Australian Government
Department of Defence
Defence Science and
Technology Organisation

Smart antennas for Safeguarding Australia

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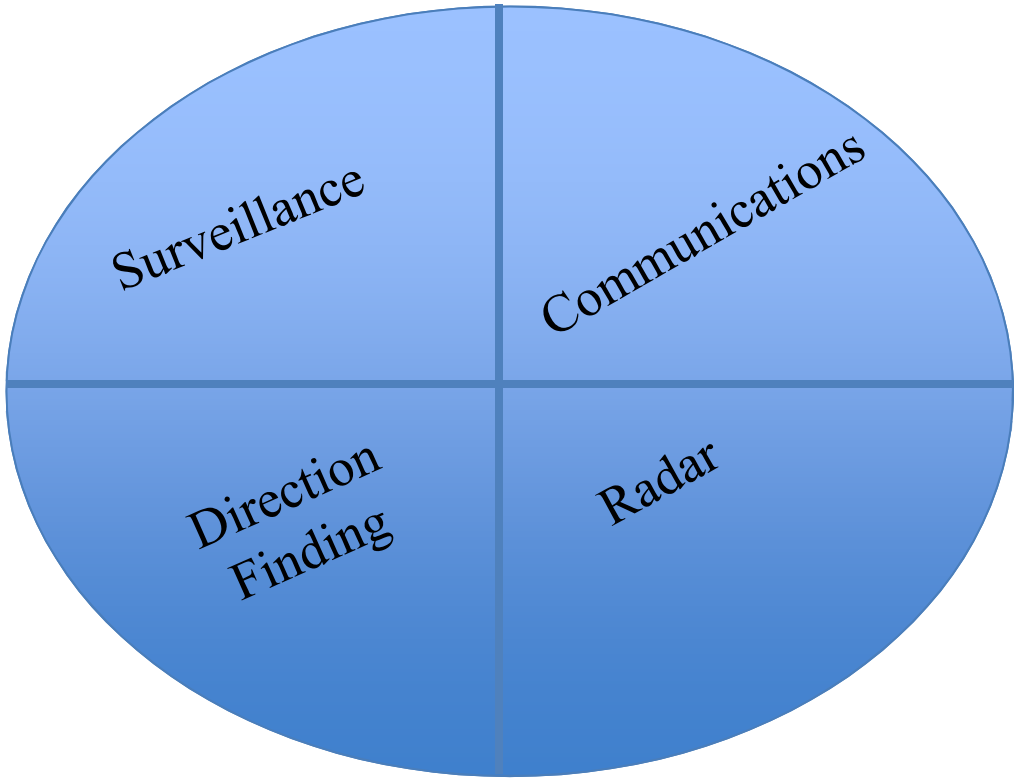
DSTO | Science and Technology for Safeguarding Australia

Antenna Technology

Overview

- Critical for Defence and National Security
  - Past achievements
- Applications
  - Surveillance
  - Communications
  - Direction Finding
  - Radar
- Collaboration
- Looking to the future
  - Some speculation

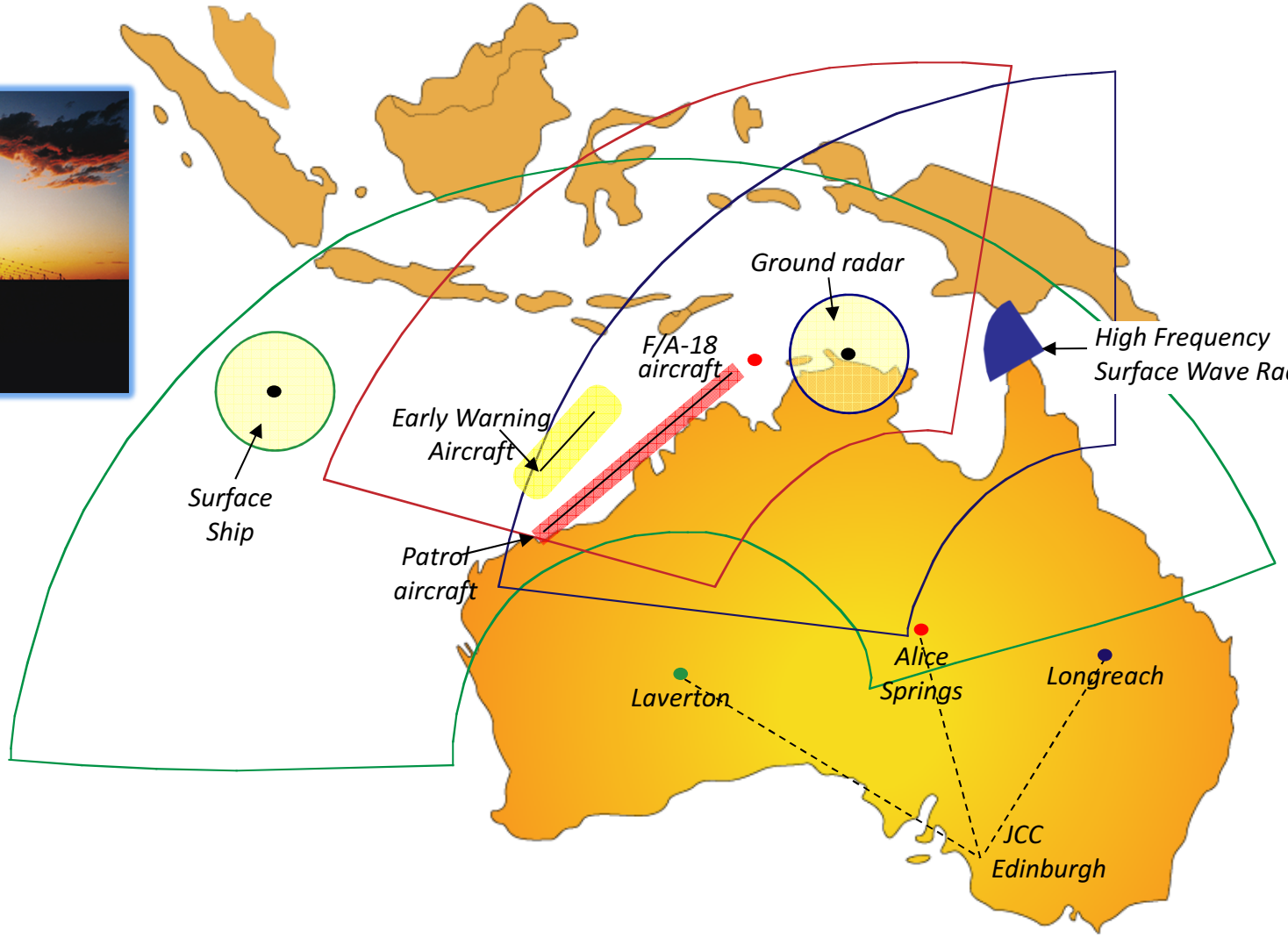


Surveillance:

Jindalee Operational Radar Network (JORN)

- JORN – Three radar network
  - Longreach QLD
  - Laverton WA
  - Alice Springs, NT
- Wide area surveillance of northern Australia
- World leading OTHR technology
- Digital array on both the transmit and receive systems

Development of Over-The-Horizon Radar Jindalee



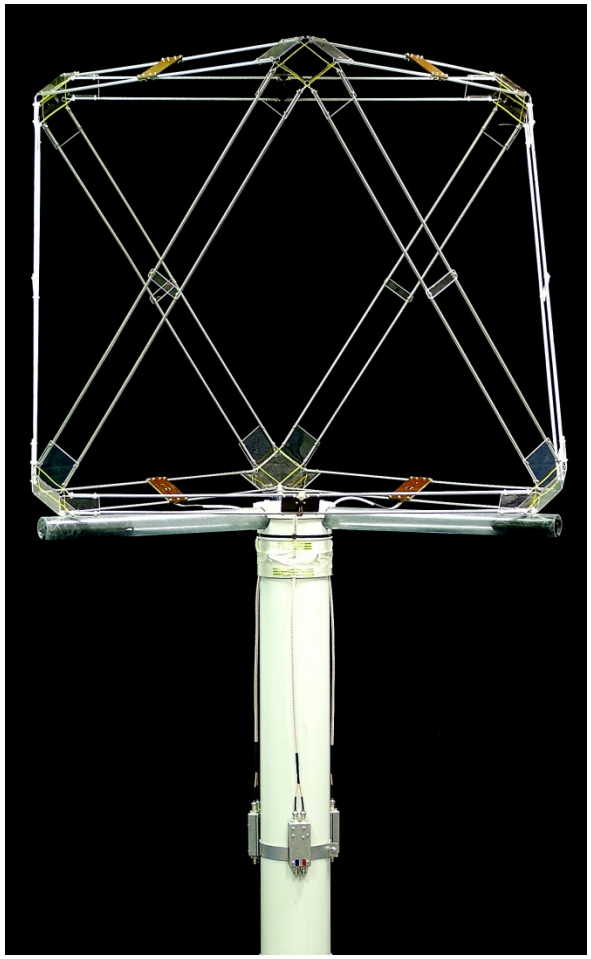
Countermeasure: Nulka Anti-ship Missile Decoy

- RF decoy used to seduce missiles away from ship target
- Nulka used on Australian, US and Canadian ships
- Most successful Australian defence export → $1 Bn
- Antenna development was crucial to capability
  - Antenna must be correctly oriented to achieve required performance

Direction Finding:

Ground Symmetric Loop Giselle Antenna Project

- Traditional loop antennas have shortfalls
  - Ground interactions
  - Distributed inductance and capacitance limit bandwidth
- DSTO developed ground symmetric loop antenna “Giselle”
  - Unique design with 3 orthogonal loops
  - 2 to 30 MHz
  - Polarization sensing
  - High noise (but less than background)
  - Easy to transport and set up
  - Accurate Direction Finding
- Giselle – compact, portable, broadband HF antenna to locate source of enemy HF communications



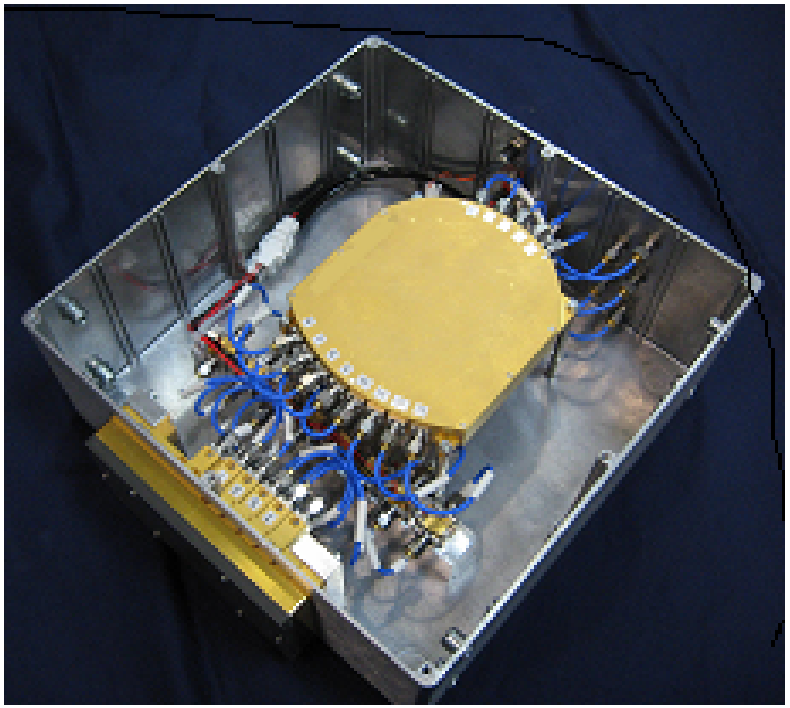
US interest in Giselle

- US Space & Naval Warfare Center (Pacific) interested in HF vector sensing Direction Finding antennas
- Giselle antenna fit the bill and supplied to US in exchange for characterised results
- Giselle antenna undergoing long-term evaluation in US
- Being used as the baseline for other HF vector sensing DF antennas

Surveillance:

Effective Area and Wide Angle Viewing

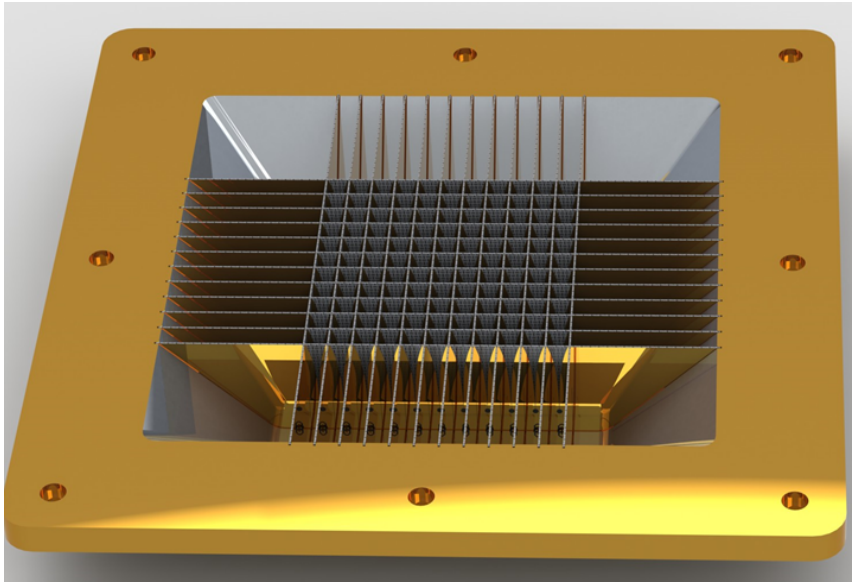
- Passive RF sensors need large effective area for sensitivity
  - At high frequencies can give a narrow field of view
- Long integration times and/or high probability of detection requirements prohibit scanning solutions
- Rotman lens forms array of small elements into multiple high gain beams
  - High effective area for each beam
  - 60° system field of view
  - 70 → 100 GHz operation at -20 dB return loss



mm Wave multi-beam receiver

Surveillance: Wide Band Microwave Antenna

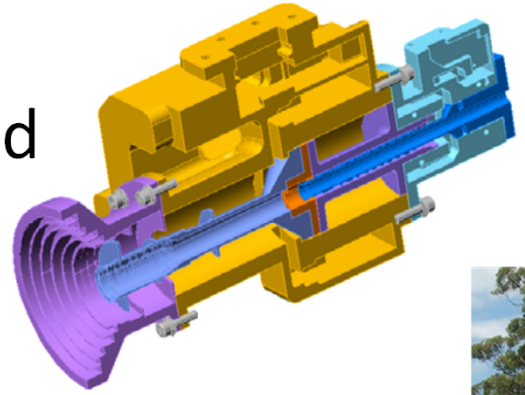
- Need:
  - Multi-octave operation
  - Wide field of view
  - Large effective area
  - Dual polarization
  - Well matched to uniform excitation
- Based on a Vivaldi antenna suitable for any frequency due to scalability
- Prototype:
  - 242 elements (11x11 dual pol)
  - 8 → 20 GHz operation
  - 169 components!



Communications:

Multi-Band Tactical SATCOM Terminal

- First simultaneous compact dual band SATCOM terminal



- Used CSIRO developed X/Ka band feed with DSTO terminal
  - X- (~7 to 8 GHz)
  - Ka-band (~20 GHz & ~30 GHz)
  - Built upon CSIRO radio astronomy feed expertise

Communications: Conformal Antennas

- Goal – high power antenna as part of the structure
  - No additional weight
  - Must be load bearing
  - Must go where structure needs to be
- Slotted Waveguide Stiffened Structure (SWASS)
- Employs meta-material concepts to minimise size of radiating structure
  - ≈ 0.1 λ slots
  - 8 → 12 GHz operation

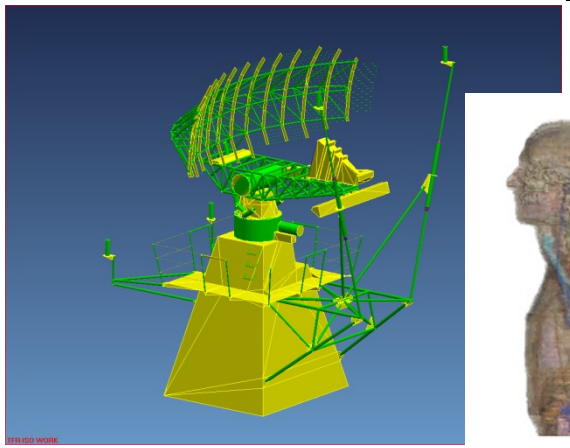
- Application to UAV surveillance: distributed aperture over skin

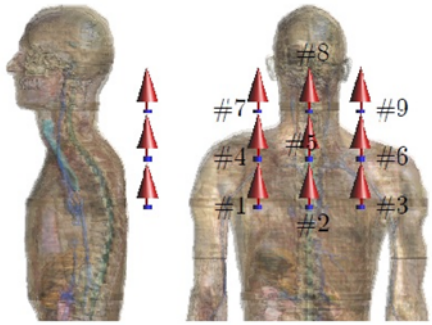
Radar: Wide band HF Antenna Array

- Mode-selective (MIMO) OTHR
  - Significant reduction in ionosphere distortions
  - Improves detection of small surface vessels
  - Requires wide band array antenna
  - Array coupling a significant concern
- Grail antenna:
  - 8 – 20 MHz
  - Excellent power handling
  - Tightly managed mutual coupling

Antenna Interactions in Challenging Environments

- Want to use antennas in “bad” places
  - Complex structures
  - Near “unknown” and variable ground materials
  - On people carrying lots of metal





- Requires modelling and measurement of embedded antenna performance

- Poor performance may have unacceptable consequences

What we want from an "ideal" antenna

- Multi-octave operation
- Compact antenna with a large effective area
- Wide angular response
- No side lobes
- Low production and maintenance costs
- Long operational life

I want an antenna with…
high gain and wide field of view…

There might be a problem ….

8 octaves of bandwidth…
compact…light weight

That's difficult ….

Low signature…good power handling…
no side lobes…

A bit of research required …

Works underwater…next Wednesday

Can you compromise that specification a bit?

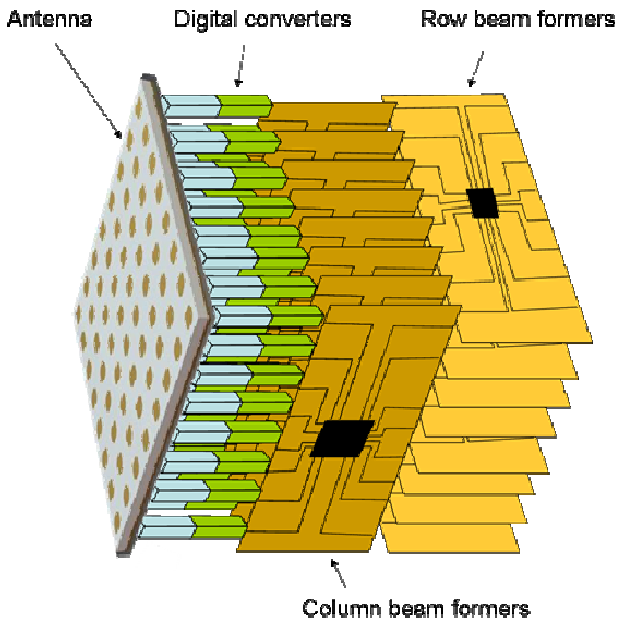
Collaboration

- Jindalee Operational Network – Telstra; RLM Systems
- Nulka – BAE Systems
- Giselle – US Space & Naval Warfare Center
- Slotted Waveguide antenna – US Air Force Laboratory
- Multi-band SATCOM terminal – CSIRO
- Body-worn RF antenna – Adelaide University

Near Future – Smart Digital Wide Band Array

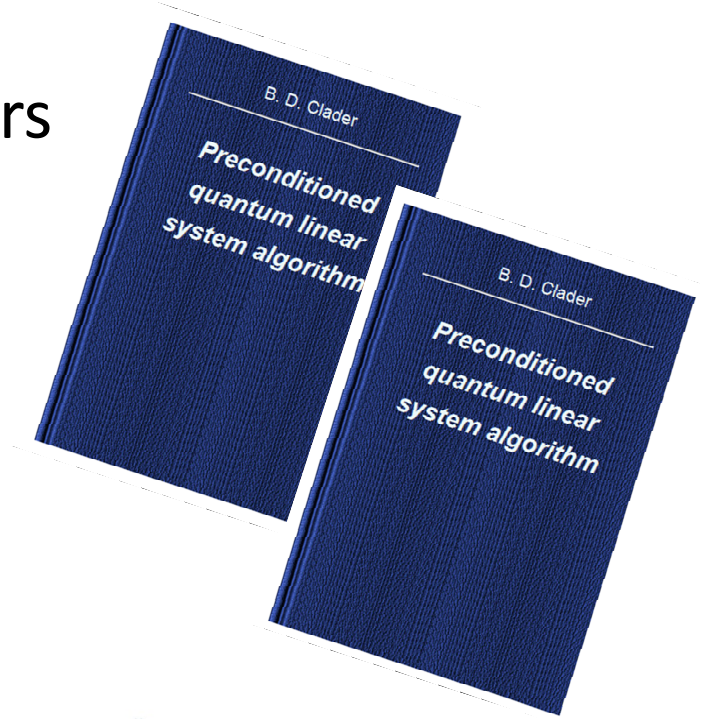
- Wide band elements
  - Direct 3D printing of element and support structures
- Embedded wideband direct digital interface
  - Transmit and receive
- Simultaneously form very large number of receive beams
- Adaptive/optimal beam forming?

- Flexible application to:
  - Radar and radar imagery
  - Communications
  - Electronic surveillance



Far Future – Improved Computation Tools

- Electro Magnetic modelling of large (e.g. ship) structures is “difficult”
- Electro Magnetic finite element modelling has been identified as a problem suitable for Quantum computers
  - Exponentially faster than classical algorithm!



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Thank You and Questions

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